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Laboratories Technically Qualified to Test Solar Collectors in Accordance with ASHRAE Standard 93-77: A Summary Report

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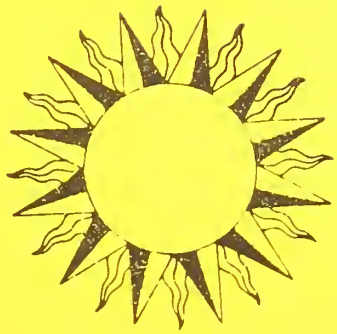
Building Economics and Regulatory Technology Division
Center for Building Technology
National Engineering Laboratory
National Bureau of Standards
U.S. Department of Commerce
Washington, D.C. 20234

November 1978



Prepared for
Department of Energy
Office of the Assistant Secretary
Conservation and Solar Applications
Washington, D.C. 20545

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PREFACE

In fulfilling its responsibilities under the National Program for Solar Heating and Cooling of Buildings established as a result of the Solar Heating and Cooling Demonstration Act of 1974 (PL 93-409) and related legislation, the Energy Research and Development Administration (ERDA) requested the National Bureau of Standards (NBS) to develop criteria for assessing the capabilities of laboratories for testing solar collectors, to identify those laboratories qualified to test solar collectors, and to develop a plan for the certification of solar collectors.

NBS engaged the professional services of ARI Foundation, Inc. (ARIF), a subsidiary of the Air-Conditioning and Refrigeration Institute (ARI), to identify laboratories qualified to test solar collectors and to develop documentation for a solar collector certification program. ARI is a national trade association of manufacturers of air-conditioning and refrigeration equipment with established experience and background in standards development for HVAC equipment and the conduct of certification programs for such equipment.

This summary report covers the identification of qualified solar collector testing laboratories. It discusses the procedures used by ARIF, the results of their evaluation and lists the laboratories evaluated as qualified to test solar collectors in accordance with American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 93-77. It also identifies continuing activities for laboratory accreditation.

ACKNOWLEDGMENTS

This report is a summary of an investigation and evaluation of laboratories qualified to test solar collectors conducted for the National Bureau of Standards, Center for Building Technology by the ARI Foundation, Inc. (ARIF), Arlington, Virginia. Accordingly, the author wishes to thank Messrs. G. R. Munger, R. J. Evans, A. B. Newton and F. J. Reed of ARIF for their fine cooperation and support of this study.

In addition, acknowledgment is also made to the many individuals and organizations that provided ARIF with information concerning their laboratories and operations.

The many helpful suggestions pertaining to this study and report provided by Carl Conner of the Department of Energy and William Freeborne of the Department of Housing and Urban Development are also gratefully acknowledged.

I. Introduction

The use of solar heating, cooling and domestic hot water systems in buildings has been on the increase in this country since the advent of the Solar Demonstration Program for Residential and Commercial Applications. These solar systems consist of conventional heating, ventilating and air conditioning (HVAC) components such as furnaces, fans, pumps, piping, etc. and solar unique components such as solar collectors. As protection to the consumer and assurance of quality and performance, the conventional components are tested and certified by nationally recognized laboratories and institutions. As examples, gas furnaces are tested and rated by the American Gas Association (AGA), electrical equipment by Underwriters Laboratories (UL), and air conditioning units by the Air-Conditioning and Refrigeration Institute (ARI). After testing the components under approved methods of test and standard conditions, the performance of the units is formally certified and their ratings published. No similar national testing and certification process presently exists for solar collectors.[1/]

1/ In response to state legislation effective October 1, 1976, the Florida Solar Energy Center (FSEC) developed standards and criteria for solar collectors sold or manufactured in Florida and currently maintains a testing facility to evaluate the performance of such collectors. Two documents which control the collector certification program were published by the Center; FSEC 77-5 (was 76-1), "Test Methods and Minimum Standards for Solar Collectors," and FSEC 77-6 (was 76-2), "Operation of the Collector Certification Program."

The California Energy Resources Conservation and Development Commission (ERCDC) has developed a Testing and Inspection Program for Solar Equipment (TIPSE) which was implemented in early 1978. Under this program, solar equipment will be certified for use in California if certain minimum criteria are met which include the completion of various tests to be performed in private laboratories accredited by ERCDC. They have also issued two reports, "Guidelines for Certification of Solar Equipment" (no number), and "Standards and Procedures - Accreditation of Testing Laboratories for Solar Components and Systems" (no number). As of June 15, 1978, ERCDC has accredited six (6) laboratories for testing solar equipment.

There are currently more than 200 manufacturers of solar collectors. Claims are made by them concerning the efficiency and performance of their collectors. Some of these claims may be exaggerated and misleading. Since the solar collectors are a major element of the cost of solar systems, the consumer can invest thousands of dollars for equipment that may not perform as expected or produce the savings in energy costs anticipated.

Standard testing, validation and certification processes are necessary to protect the consumer and the market for solar systems. This fact was anticipated by Congress when they enacted the Solar Heating and Cooling Demonstration Act of 1974 (PL 93-409). Section 8 of this act states that, as soon as feasible, the Secretary of Housing and Urban Development shall determine, prescribe and publish in the Federal Register procedures whereby manufacturers of solar heating and combined solar heating and cooling components and systems shall have their products tested in order to provide certification that such products conform to the established performance criteria.

Based on PL 93-409 and related legislation[1/], the Energy Research and Development Administration (ERDA), now the Department of Energy (DoE), released a report designated ERDA-23A[2/], dated October 1975 and entitled the "National Program for Solar Heating and Cooling (Residential and Commercial Applications)." A task in this National Program Plan stated that "To certify that the solar energy systems meet a given set of criteria, private laboratories must be capable of testing such systems and ultimately provide a method of labeling. To accomplish this, private laboratories must be capable of meeting minimum standards. Support will be obtained from the American Society for Testing and Materials (ASTM), American National Standards Institute (ANSI), and other appropriate groups in the development of minimum laboratory standards and to insure that private laboratories will be available to carry out necessary testing programs once solar heating and cooling become a part of the normal market process." DoE/CS-0007[3/], "National Program for Solar Heating and Cooling of Buildings," dated July 1978 updates the research,

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1/Solar Energy Research, Development and Demonstration Act (PL 93-473).

Energy Reorganization Act of 1974 (PL 93-438).

Federal Nonnuclear Energy Research and Development Act of 1974 (PL 93-577).

2/Available from DoE Technical Information Center, P.O. Box 62, Oak Ridge, Tenn. 37830.

3/Available from Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402 - Stock Number 061-000-00136-1.

development and demonstration program activities outlined in ERDA-23A. DoE/CS-0007 continues to cite the need for a procedure to accredit testing laboratories and reports on efforts to identify laboratories capable of performing collector tests. It further states that such efforts will be integrated into a more comprehensive program of laboratory accreditation under the National Voluntary Laboratory Accreditation Program (NVLAP).

In fulfilling its responsibilities under the national program for establishing criteria for the accreditation of testing laboratories, ERDA requested the National Bureau of Standards (NBS) to develop criteria for assessing the capabilities of laboratories for testing solar collectors, to identify those laboratories qualified to test solar collectors, and to develop a plan for the certification of solar collectors.

Because of their background and experience in the development of standards and in the conduct of certification programs, the National Bureau of Standards entered into a contractural arrangement with ARI Foundation, Inc.[1/] (ARIF), a subsidiary of the Air-Conditioning and Refrigeration Institute (ARI), to accomplish the following:

1. To identify laboratories qualified to test solar collectors in accordance with ASHRAE Standard 93-77[2/], and
2. To develop documents (i.e., proposed solar collector rating standard, certification program operational manual) for a solar collector certification program.

The Air-Conditioning and Refrigeration Institute (ARI) is a national trade association of manufacturers of commercial and industrial air-conditioning and refrigeration equipment and central residential air-conditioning equipment that is very active in the standards development for HVAC equipment. They have issued 52 standards covering various types of HVAC equipment and components. In addition, ARI has developed and are administering 11 certification programs for certain types of HVAC equipment which involve the use of an ARI Certification Seal for equipment manufactured and rated in accordance with the applicable ARI standards, following validation by an independent laboratory.

1/ARI Foundation, Inc., 1815 North Fort Myer Drive, Arlington, Virginia 22209.

2/ASHRAE Standard 93-77, "Methods of Testing to Determine the Thermal Performance of Solar Collectors," February 1977, American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 345 E. 47th Street, New York, NY 10017 - price $8.00 per copy + $.35 per copy for postage and handling.

This summary report covers the identification of qualified solar collector testing laboratories. ARIF prepared a separate report for the solar collector certification program.[1/]

[1/] NBS-GCR 78-125, "Report on Organization of Certification Program for Solar Collectors." Available from NTIS, Order Number PB-280025, price $6.00

II. Procedures

In order to identify testing laboratories having the desire and technical capability to conduct thermal performance tests of solar collectors in accordance with the ASHRAE Standard 93-77, ARIF issued a news release entitled, "Need for Solar Collector Testing Facilities," to various technical publications and trade journals in December 1976. The release requested interested laboratories to contact ARIF.

Those laboratories that responded to the news release and those whose names were taken from other available lists such as the laboratories involved in the NBS Round-Robin Test Program for Solar Collectors were sent a preliminary questionnaire with an explanatory letter, a draft copy of ASHRAE Standard 93P (which later became ASHRAE Standard 93-77 in February 1977), and a copy of ASTM E548-76[1/], "Generic Criteria for Use in the Evaluation of Testing and/or Inspection Agencies." The preliminary questionnaire was an abbreviated data sheet soliciting information upon which to make a judgment on whether a laboratory should be considered for participation in the program. The preliminary questionnaire was sent to 138 organizations, 93 of which were commercial, manufacturer's, university, Federal, or state testing laboratories.

Those laboratories that responded to the preliminary questionnaire and indicated that they did not have test facilities available which could qualify for testing solar collectors per ASHRAE Standard 93-77 were promptly notified that no further action would be taken on their questionnaire. They were invited to notify ARIF at such time as a suitable laboratory facility had been built and had become available for testing solar collectors. All other laboratories that responded to the preliminary questionnaire were sent a more detailed one which required responses to questions concerning conflict of interest, ASTM E548-76 requirements, quality control, ASHRAE Standard 93-77 requirements, and some specific testing activities.

Before the transmittal of either questionnaire to the laboratories, NBS convened a committee composed of representatives of collector manufacturers (both air and liquid types), testing laboratories, and Federal and state agencies in January 1977 to review the preliminary and detailed questionnaires plus the evaluation criteria for each which had been proposed by ARIF. Suggested modifications agreed upon at this meeting were incorporated into the questionnaires and the criteria. (See Appendix A for Forms SARIF-1 and SARIF-2 Questionnaires, and their respective Criteria).

1/Available from American Society for Testing and Materials, 1916 Race Street, Philadelphia, PA 19103.

To be sure that no laboratory that felt qualified to test solar collectors and had an interest in participating in this program was overlooked, the National Bureau of Standards sent out another news release in June 1977 announcing the program "to identify qualified solar collector testing laboratories."

Thirty-eight (38) laboratories responded to the preliminary questionnaire. Evaluation of these responses showed that three laboratories had no solar facility at the time of the response, and these were invited to notify ARIF when their solar facility was ready. The remaining thirty-five (35) laboratories were sent the more detailed questionnaire for completion. Of this group, nineteen (19) laboratories chose not to return the latter questionnaire. One of the sixteen (16) laboratories that did respond submitted an incomplete response indicating that their solar facility was still under construction. No action was taken in this case and the laboratory was so notified.

The responses from the remaining fifteen (15) laboratories were reviewed and evaluated. Laboratory facility visitations for these labs were conducted between February and October 1977. The purpose of the facility visits, in part, was:

- o to meet the personnel responsible for the management of the laboratory and the conduct of tests,
- o to discuss the detailed questionnaire responses,
- o to verify their statement on conflict of interest,
- o to examine the laboratory test facilities and procedures, and test specimen and data security provisions,
- o to discuss plans for the test facility.

Earlier this year, DoE solicited proposals from industry regarding the testing of solar collectors for thermal performance and reliability characteristics. As part of the proposal evaluation process, DoE requested NBS to provide additional information concerning the qualifications of some of the proposal respondees, all of whom had been evaluated by ARIF. In addition, there was one laboratory that had not been previously evaluated by ARIF. Accordingly, NBS requested ARIF to conduct additional laboratory facility visitations for these several laboratories in April and May 1978.

III . Results of Evaluation

The responses from the sixteen (16) laboratories were evaluated against the criteria that were developed for the detailed questionnaire (SARIF-2). These evaluations coupled with the laboratory facility visit(s) and evaluation formed the basis for establishing a laboratory's qualifications to test solar collectors in accordance with ASHRAE Standard 93-77. It should be pointed out that the ARIF evaluation team did not witness or monitor the actual test of a solar collector or the instrumentation calibration procedures at each laboratory during their facility visit. The ARIF evaluation is based, in part, on a visual inspection of each test laboratory including its solar test facilities plus verbal information from qualified laboratory personnel.

Based on the ARIF criteria and visits, eleven (11) laboratories were considered technically qualified to perform thermal performance tests in accordance with the ASHRAE 93-77 procedure using existing instrumentation, test stands and personnel. All laboratories had performed some collector testing. However, based on their questionnaire responses and their facility evaluation, some laboratories had completed more solar collector testing than others. The laboratories determined to be qualified at the time of the lab visit(s) and their capability with respect to type of test stand (liquid or air) and location of test stand (indoors or outdoors) are shown in the following table.

Laboratory	Date of Lab Visit		Type of Stand		Location of Stand	
	Initial	Follow-Up	Liquid	Air	Indoors	Outdoors
1. Approved Engineering Test Laboratories 15720 Ventura Boulevard Encino, CA 91436 (213) 783-5985 Mr. Robert Finch	7/28/77	4/26/78	✓[1]	✓[1]	---	✓
2. The Boeing Aerospace Company P.O. Box 3999, M/S 86-01 Seattle, WA 98124 (206) 773-8516 Mr. Paul T. Sauber	7/25/77	4/27/78	✓[1,5]	✓[1,5]	✓[5]	---
3. Desert Sunshine Exposure Tests, Inc. Box 185 Black Canyon Stage Phoenix, AZ 85020 (602) 465-7521 Mr. Gene A. Zerlaut	7/29/77	4/24/78	✓[2]	✓[1]	---	✓
4. Florida Solar Energy Center 300 State Road 401 Cape Canaveral, FL 32920 (305) 783-0300 Dr. Charles Beach	3/ 1/77	---	✓	---	---	✓
5. Honeywell-Energy Resource Center 724 Harding Avenue, N.E. Minneapolis, MN 55413 (612) 379-1141 Mr. Al Baldwin	8/25/77	---	✓[3,6]	✓[3,4,6]	✓[3,6]	✓[6]
6. Johnson Environmental and Energy Center The University of Alabama at Huntsville P.O. Box 1247 Huntsville, AL 35807 (205) 895-6361 Dr. B. J. Schroer	7/20/77	5/ 1/78	✓	✓[7]	---	✓
7. Lockheed Palo Alto Research Labs 3251 Hanover Street Palo Alto, CA 94304 (415) 493-4411 Mr. R. K. Wedel	7/27/77	---	✓	---	---	✓

Laboratory	Date of Lab Visit		Type of Stand		Location of Stand	
	Initial	Follow-Up	Liquid	Air	Indoors	Outdoors
8. Physical Science Laboratory New Mexico State University Box 3-PSL Las Cruces, NM 88003 (505) 522-4400 Mr. W. C. Stevens	4/24/78	---	✓	✓[7]	---	✓
9. Solar Energy and Energy Conservation Laboratory Mechanical Engineering Dept. University of Florida Gainesville, FL 32611 (904) 392-0818 Mr. C. A. Morrison	8/31/77	---	✓	---	---	✓
10. University of Connecticut Solar Energy Evaluation Center Box 7-139 Storrs, CT 06268 (203) 486-2090 Mr. David R. Jackson	6/ 8/77	9/ 9/77	✓	✓	---	✓
11. Wyle Laboratories Solar Energy Systems Division P.O. Box 1008 Huntsville, AL 35807 (205) 837-4411 Mr. David R. Reese	9/ 1/77	5/ 1/78	✓[1]	✓[1]	---	✓

NOTES:

1. Laboratories which had performed limited solar collector thermal performance testing.
2. Laboratory has altazimuth stands.
3. Laboratory has an indoor simulator with a 4 ft. by 4 ft. light bank which is equipped for either air or liquid testing.
4. Laboratories had outdoor air test stands under construction at the time of the ARIF visit. The facility would probably be acceptable; however, final inspection and evaluation of the operational installation is required before qualification.
5. This laboratory is qualified based on its meeting the spectral distribution specified in ASHRAE Standard 93-77 (i.e. the use of filters may be required to reduce the UV from the light source in their A-7000 Simulator). The use of a mirror at the appropriate angle in the collimated beam may also be required to allow an angled position of the collector in test.
6. This company is only interested in testing products it makes (itself or jointly with others) and, if requested, to do developmental testing for other manufacturers.
7. Air collector test facility was not operational at the time of the lab visit (initial or follow-up). However, it was near enough to completion so that a judgment could be made as to its suitability.

IV. Conclusions and Recommendations

It should be recognized that this study to establish criteria, evaluate capabilities, and identify solar collector testing laboratories technically qualified for performing a standard test in accordance with ASHRAE Standard 93-77 represents the initial effort to provide accredited measurement facilities on a national basis. It should be further recognized that this study is limited since only thirty-eight (38) laboratories responded to the initial questionnaire and, of these, only fifteen (15) submitted the more detailed questionnaire. This number was further reduced to ten (10) as a result of the laboratory visits. Because of the laboratory evaluations and visitations required to satisfy DoE's needs for their Solar Collector Testing Program, an additional laboratory has been evaluated as qualified to test in accordance with the ASHRAE Standard. It is believed that these eleven (11) laboratories will provide an adequate geographic and climatic base to implement an accreditation program.

It should be noted that those laboratories that are not listed herein, additional laboratories that did not desire to participate in this program and laboratories that were in the process of developing their facilities may wish to participate in future voluntary accreditation programs.

V. Continuing Activities

As stated in DoE/CS-0007, "National Program for Solar Heating and Cooling of Buildings," the efforts to identify laboratories capable of performing collector tests, i.e., the results of this study, will be integrated into a more comprehensive program of laboratory accreditation under the National Voluntary Laboratory Accreditation Program (NVLAP).

The NVLAP was established with the publication of a notice in the Federal Register on February 25, 1976 in which the Department of Commerce made known the operating procedures for the program, in Part 7, Title 15, Code of Federal Regulations. The NVLAP establishes a national voluntary system that would examine the professional and technical competence of testing laboratories that serve regulatory and non-regulatory product evaluation and certification needs. Laboratories that meet the qualifications established as a result of the aforementioned procedures would be accredited. The intended goal of the NVLAP is to serve, on a timely basis, the needs of industry, consumer, the Government, and others by accrediting this nation's testing laboratories.

In addition to integration into the NVLAP, the results of this laboratory investigation and evaluation will be submitted to the Solar Energy Research and Education Foundation[1/] (SEREF) for use in their on-going contract effort for the Department of Energy to design a program which will provide for solar collector performance and physical testing, rating, certification and labeling.

Those testing laboratories that did not participate in this study who are interested in testing solar collectors and may wish to participate in continuing activities described above should contact the Solar Technology Program, National Bureau of Standards, Washington, D.C. 20234.

1/Solar Energy Research and Education Foundation, 1001 Connecticut Avenue, N.W. Suite 800, Washington, D.C. 20006

APPENDIX A

SARIF-1 Form

Information Required from Laboratories
Interested in Testing Solar Collectors
for Performance
as Prescribed in ASHRAE 93-P

1. Organization Name _____

   Address _____ Phone: _____

   Principal Contact: _____

2. Location of Test Facility _____

   Address _____ Phone: _____

   Principal Contact: _____

   Latitude _____ Elevation _____

3. Do you have a facility for outdoor testing per 93-P? Yes ____, No ____

   Do you have a facility for simulation test per 93-P? Yes ____, No ____

   If "No", are you considering obtaining these facilities? _____

4. Have you customarily done thermal performance testing of solar collectors?

   Yes ____, No ____. If "Yes", how long? _____mos. How many collectors? _____

5. Summary of Lab personnel and training. (Number in each category)

	PhD	MS	BS	Associates	High School Graduates	Others
Management						
Lab. Manager						
Test Set-up						
Instrumentation						
Test Operators						
Data Processors						
Report Writers						
Technicians						
Clerical						
Note: Indicate highest level of education for each individual.						

6. If your laboratory is interested in testing for others, provide your usual method of charging for testing:

Use of Test Stand(s)	$_____	per _____
Pre-Test	$_____	per _____
Performance Testing	$_____	per _____
Data Processing	$_____	per _____
Final Report	$_____	per _____
Other	$_____	per _____

7. Other pertinent information you wish to furnish as to your Laboratory capabilities and plans. What other comparable thermal testing have you done?

8. Laboratory Facilities.

A. Number of test stands for Air _____ Liquid _____ (Indoor)
Air _____ Liquid _____ (Outdoor)

B. Size limits for collectors Max. _____ mm x _____ mm Min._____ mm x _____ mm

C. Comments:

D. Operational Limits

	Control	Measurement
a. Temperature	^{o}C to ^{o}C	^{o}C to ^{o}C
b. Flow (max. rate) {Air / Liquid}		
c. Solar (outdoor), W/m^2		
d. Simulation, W/m^2		
e. Data processing		

Form SARIF-1

9. Special Instrumentation for Insolation.

No. of pyranometers available _____

No. of pyrheliometers available _____

Describe your practice as to calibration and frequency thereof, what standard is used as reference, etc.

10. Submitted by _____ Date _____

Typed Name _____ Phone _____

SARIF-2 Form

ADDITIONAL INFORMATION REQUIRED FROM LABORATORIES

INTERESTED IN TESTING SOLAR COLLECTORS
for PERFORMANCE
as PRESCRIBED in ASHRAE 93-P

A. Laboratories who have made acceptable responses to SARIF-1 indicating an interest and capability in becoming accepted for performance testing of solar collectors while adhering to the requirements of ASHRAE Standard 93-P, as now in draft form, and as required under Public Law 93-409, the Solar Heating and Cooling Demonstration Act of 1974, are now requested to furnish more detailed information. Part of this information will answer questions contained in ASTM 548-76 dealing with the evaluation of testing and/or inspection agencies, part will deal with testing under ASHRAE Standard 93-P, now in draft form, and part will be additional information needed for a complete review of each laboratory's capabilities.

B. In addition to the information specifically requested, it will be to your advantage to include complete vitae or professional records of your key personnel. This is particularly helpful if your laboratory is a large one and does testing in a variety of fields.

C. Your response to this request will be reviewed by a competent team under the supervision of ARI Foundation, Inc. There may be a need for a visitation by ARIF technical personnel for on site inspection of personnel and facilities. You will be notified in advance of any such visit. Please respond as completely as possible to all questions and information requests in the remainder of this document.

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1. Please verify the accuracy and completeness furnished with your response to SARIF-1. A copy is enclosed herewith for your use in case the first copy was incomplete, or in case any information has changed since you submitted the previous copy.

2. Does your laboratory or its personnel have any pecuniary interest, such as being an officer or owning significant stock of a company engaged in the manufacture or sale of solar collectors? Yes _____. No _____.

   If yes, give details below or on additional sheets.

ASTM E548 Requirements

3. Your complete response to all requests in this section will be important in determining the desireability of including your laboratory in the solar collector testing program.

4. Please show the organizational structure and the lines of responsibility as they exist in your operation. This may be done on a separate sheet of paper as for example by an organization chart.

5. Give job descriptions of key management and technical personnel. A separate sheet for each person may be supplied.

6. From your personnel records suppy the qualifications, work experience, training history, of each person who will be closely associated with any solar collector facility or testing.

7. Describe programs operated by your laboratory which are intended to assure continued competence of the laboratory's human resources.

8. Describe why you believe your laboratory is well suited to testing of solar collectors by methods described in ASHRAE Standard 93-P. This information may include comments on the geographic location(s), the number of indoor simulators and outdoor test stands you possess, the adequacy of your instrumentation, and methods of data processing.

9. Describe the types of inspection and instrumentation equipment you customarily employ in your test facility.

10. Describe your calibration procedures for various devices, and the program for assuring continued accuracy.

11. Do you have a library of standards and procedures? List typical material contained therein.

12. Describe your facilities for storage and protection of collectors before and after testing.

13. What logistic services do you employ? Have you been able to provide continuous operation of all tests without interruption from lack of supplies?

14. Describe the data processing equipment you employ. What accuracy can it consistently achieve? Will it be used in connection with solar tests?

Quality Control

15. Describe the calibration devices employed for the various types of instrumentation used in your laboratory. In your opinion, will the same devices and procedures be adequate for testing of solar collectors?

16. To what degree have you standardized the methods of testing and securing data? Has this allowed a determination of the expected accuracy for the various regimes of testing?

17. It is well recognized that physical values, calibration and numerical standards must be traceable to National or other standards. How is this traceability provided in your laboratory to provide reliable data recording, processing and reporting?

18. Describe any use made in your laboratory of specimen sampling programs to establish and validate quality control.

19. In what ways does your laboratory use statistical analysis to assure consistency and best fits in the presentation of data and its analysis? Give details of the application of statistical processes to the various types of testing which will apply to determination of performance of solar collectors.

20. Feedback and cross-checking is a useful method of locating discrepancies in data or its reduction. What provisions do you employ to use feedback to find and correct problems? Do you employ peer review, either by consultation or by checking a particular test with another laboratory? Will these methods be employed for maintaining the quality of solar collector testing?

21. To what degree do you employ audit sampling of test results to maintain consistency and accuracy? How do you implement this technique?

22. Do you practice frequent on-site reviews to assure the best test and operating methods? Do such reviews utilize personnel from other test areas to broaden such investigations and bring additional expertise into the analysis?

23. How comprehensive are the reviews of Item 22? How do you ascertain that proper feedback is obtained from such reviews? How do you ascertain that improvements suggested from such reviews are implemented at as early a date as possible? Do you then make rechecks of the improvements obtained?

93-P Requirements

24. Please give an overview of why you believe your laboratory has the ability to test solar collectors for performance per Section 8 of ASHRAE Standard 93-P.

25. Describe your provisions for the three-day stagnation test required of each collector before performance testing. You should include your estimate of the elapsed time such tests may require in your area due to prolonged periods with insufficient insolation. You may also describe any planning you have to provide such tests on an indoor simulator.

26. Do your outdoor test locations, including those for stagnation tests, show freedom from reflections which can invalidate a test? How have you determined this reflection factor? Do foreground areas around test stands have less than the prescribed reflectivity of 0.20?

27. List the number of pyranometers and pyrheliometers meeting the "first class" category of the World Meterological Organization which your laboratory possesses. Does this number meet the requirements for performance of the number of simultaneous tests of collectors planned at your facility?

28. Do the instruments of Item 26 provide ambient compensation to maintain accuracy to ±1% thruout a temperature range of -20 to +40 ^{o}C?

29. It is necessary to assure that the output of the instruments of Item 26 can be viewed as linear within ±1%. How is this accomplished?

30. Provide assurance that the time response of the instruments of Item 26 is not greater than 5 seconds.

31. Describe your provisions to assure that each instrument of Item 26 is within 1% of being proportional to the cosine of the zenith angle.

32. What means do you employ to prevent condensation within the instruments of Item 27 during use? Comment on how satisfactory the results of this method of control have been.

33. Describe your provisions to assure that each instrument of Item 26 is calibrated to a known standard within 6 months of its use in any test. What magnitude of deviations have been encountered during this period?

34. It is necessary to measure the direct component of insolation during tests. How does your laboratory calibrate its pyranometer when it is in a tilted

34. position? Have your results been consistent?

35. Standard 93-P requires the use of ASHRAE Standard 41.1-75 when measuring temperatures. Is your laboratory using this standard in other testing involving temperature measurement?

36. Refer to Paragraph 6.2.2 of ASHRAE Standard 93-P and indicate any problems you might foresee in meeting the accuracy and precision required in measurement of temperature.

37. Describe the provisions used in your laboratory for making accurate temperature differential measurements.

38. Provide assurance that the smallest scale division of all temperature measuring devices which will be employed in testing of solar collectors does not exceed twice the required precision of the device.

39. Identify the types of flow measurement devices which you will employ for air and/or liquids. Provide assurance that measurements made therewith will have an accuracy within ±1% of the measured value in mass units.

40. Provide assurance that strip chart recorders to be used in testing of solar collectors have an accurancy of ±0.5% of full scale, and that their time constant is less than 1 second.

41. Provide proof that any electronic integrators you use can provide results equal to or better than 1% of measurement.

42. Give assurance that the measuring techniques used by your laboratory for nozzle throat pressures provide readings within an accuracy of ±1% of any reading, and scale divisions do not exceed 2% of reading.

43. Show that your manometer calibrations are accurate to ±1% of any reading.

44. Provide assurance that the manometer to be used for measuring the Δp across the collector has an accuracy of at least 25 Pa (0.1" water).

45. Describe your provisions for calibration of time and mass measurements to an accuracy of ±0.20%.

46. Describe your approach to measurement of wind velocity to ±0.8m/s, (± 1.8 mph).

47. It is intended that all laboratories taking part in this test program will use test configurations shown in Figures 1 thru 4 of ASHRAE Standard 93-P as applicable. Will your laboratory meet these configurations in their

47. testing when testing collectors? If there are any departures comtemplated, define and defend them.

48. Provide assurance that your method of measuring outdoor ambient temperature conforms to the standard NOAA device completely.

49. How do you measure the direct component of insolation? Do you have adequate instrumentation to do so?

50. Does your laboratory have calibrated flow elements for measuring small air flows, for example the nozzle referenced as being less than 0.025m (1") in diameter. If not, do such small measurements present a problem which would require additional instrumentation?

51. Provide assurance that the air re-conditioning apparatus used with air type collectors is capable of controlling the inlet air temperature to the collector within $\pm 1.0^{o}C$ ($1.8^{o}F$).

Testing by Simulator

52. If your laboratory includes a solar simulator provide assurance that the spectral qualities of the radiation produced by the simulator meets the energy spectrum of Paragraph 7.3.1 of ASHRAE 93-P.

53. Provide assurance that using the radiation from your simulator, the absorptivity of the selective surface specified in 93-P Paragraph 7.3.1 does not change over 1% for a change in radiation flux of 0.45 to 0.75 of one solar constant.

54. Show that the solar simulator beam does not vary more than 7% over the test plane.

55. Provide assurance that 95% or more of the energy output of the simulator appears within a 10^{o} subtended angle.

Testing

56. Describe your plans for determining the collector time constant.

57. Provide assurance that your laboratory is equipped to test at several incident angles other than normal incidence as required to determine the factor "b" used in Equation 8.14.

58. Provide assurance that your laboratory can provide all facets of the required solar testing, - 1, by outdoor test, and/or 2, by indoor simulation.

59. Provide assurance that the laboratory can perform the required tests to determine the collector incident angle modifier as per paragraph 8.3.2 of ASHRAE Standard 93-P.

60. Discuss your method of calculating the collector time constant.

61. Describe your method of providing a least squares fit to the applicable second order polynominal obtainable from your data points.

62. Discuss the method you will use to accurately compute the incident angle modifier.

63. Discuss the reliability with which your laboratory can provide all applicable information from tests of specific collectors required by Table A13.

64. Discuss the ability of your laboratory to accurately provide all information required by Table 14 of ASHRAE Standard 93-P for each collector tested.

General

65. University laboratories who use students to perform all or a portion of the testing must discuss the degree and type of supervision provided.

66. List or describe any intangibles you feel to be pertinent to the operation and effectiveness of your laboratory. Any other information you feel will be useful to the reviewers may be detailed at your option.

Evaluation Criteria for SARIF-1 Form

CRITERIA FOR FORM SARIF-1

1 & 2. a. Degree to which the location of the laboratory permits outdoor collector testing with good continuity.

b. Relative geographic location with respect to manufacturers and others who are expected to need collector testing.

3. a. Degree of readiness for outdoor testing requirements of 93-P.

b. Existence of simulation facility capable of testing per 93-P.

4. Experience level in terms of months of operation and number of collectors tested. 12 months of full operation and testing of 3 or more different collectors are considered a good experience.

5. a. An in-depth organization should be indicated regardless of its size. Variations due to size and type should be considered.

b. Degree to which necessary capabilities for testing, accuracy, data reduction, report writing, and record keeping are indicated. Consideration as to mix must be given considering the type of laboratory, - i.e., university, private, research organization, industrial.

6. a. Interest in testing for others, with possible exception of those laboratories operated by collector manufacturers.

b. Existence and completeness of suitable cost schedules for tests made for others.

7. Evaluation of comparable thermal testing for relevance to solar tests.

8-A. a. Degree to which existing test stands are available to test <u>indoors</u> with <u>air</u> as the heated medium.

b. Degree to which existing test stands are available to test <u>indoors</u> with <u>liquids</u> as the heated medium.

c. Degree to which existing test stands are available to test <u>outdoors</u> with <u>air</u> as the heated medium.

d. Degree to which existing test stands are available to test <u>outdoors</u> with <u>liquid</u> as the heated medium.

8-B. a. Existence of test stands capable of accepting collectors up to 4 feet by 8 feet in face dimensions.

b. Existence of test stands capable of accepting collectors down to 1400 mm by 1000 mm in face dimension.

CRITERIA FOR FORM SARIF-1

8-C. Evaluation of comments.

8-D. a,b,c,d. Degree to which control and measurement meets or exceeds the requirements of ASHRAE 93-P.

e. Degree to which data processing can maintain accuracy and provide consistent results within the requirements of ASHRAE 93-P.

9. Existence of at least one pyranometer for each test stand. Existence of sufficient pyrheliometers to measure direct solar component, or satisfactory alternate for determination of direct solar component. Recalibration at a capable national laboratory every six to twelve months.

Evaluation Criteria for SARIF-2 Form

CRITERIA FOR FORM SARIF-2.

1. Verification of accuracy of information furnished in SARIF-1.

2. Evidence that laboratory has no pecuniary interest in manufacture or sale of solar collectors.

	ASTM E548 Requirements.	Page	Para.
3.	Completeness of response to information requested and relevance of material provided.	2	4
4.	Assurance of clear lines of responsibility	2	5.1.1
5.	Degree to which job descriptions of key management and technical personnel are available.	2	5.1.2
6.	Existence of adequate personnel records showing qualifications, work experience, training history of each person described in Item 5.	3	5.2
7.	Degree to which programs are provided to assure continued competence of the laboratory's human resources.	3	5.3
8.	Adequacy of solar testing laboratories, including suitability of location for solar collector testing and/or provision of indoor simulator.	3	6.1.1
9.	Degree to which required testing and inspection equipment and instrumentation is available.	3	6.1.2
10.	Adequacy of calibration standards and equipment.	3	6.1.3
11.	Existence of a library of standards and procedures.	3	6.1.4
12.	Facilities for storage of collectors before and after testing.	3	6.1.5
13.	Adequacy of logistic services.	3	6.1.6
14.	Degree of accuracy of data processing equipment	3	6.1.7
	Quality Control		
15.	Adequacy of calibration programs for all instrumentation.	3	7.1.1.1
16.	Level of standardization of methods of test, measurement, determination.	3	7.1.1.2
17.	Traceability of physical, calibration, or numerical standards, and of data recording, processing and reporting	3	7.1.1.3 7.1.1.4

	CRITERIA FOR FORM SARIF-2.	Page	Para.
18.	Existence of specimen sampling program.	3	7.1.2.1
19.	Use of statistical analysis in analyzing data.	3	7.1.2.2
20.	Feedback available on causes of discrepancies in data detected, and availability of peer review	3	7.1.2.3
21.	Degree to which a representative audit sampling of test results is employed.	3	7.1.3.1
22.	Practice of frequent on-site reviews.	3	7.1.3.2
23.	Comprehensiveness of reviews of Item 22, and existence of feedback of relevant information obtained.	3	7.1.3.3 7.1.3.4
	93-P Requirements		
24.	Overall ability to test collectors per Section 8 of 93-P.	4	5.1
25.	Provision for stagnation test, by outdoor exposure for 3 days with mean of 1500 Btu/ft^2 per day, or alternately* indoors with 24 hours at mean of 187 Btu/ft^2-hr with three excursions of 1-hour each to 350 Btu/ft^2-hr.	5	5.1.1
26.	Demonstrated freedom of reflection for outdoor testing, and reflectivity of foreground area less than the prescribed diffuse reflectivity of 0.20.	5	5.1.3
27.	Availability of sufficient pyranometers and pyrheliometers meeting the "first class" requirements of the World Meterological Organization to perform the number of simultaneous tests planned by the laboratory.	6	6.1.1
28.	Existence of ambient compensation in the instruments of Item 26 + or - 1% from -20 to +40°C.	6	6.1.1.1
29.	Existence of calibration relating output of instruments of Item 26 insolation, or assurance of linearity within + or - 1%.	6	6.1.1.3
30.	Evidence that time response of pyranometers is less than 5 seconds when irradiated at flux level of 300 Btu/sq ft hr.	7	6.1.1.4
31.	Assurance that response of instrumentation of Item 26 to changing angles of incidence is within 1% of being proportional to the cosine of the zenith angle of the direct solar radiation.	7	6.1.1.5
32.	Assurance of adequate means to prevent condensation in the instruments of Item 26.	7	6.1.1.6

*Under consideration by ASHRAE 93 Committee

	CRITERIA FOR FORM SARIF-2.	Page	Para.
33.	Existence of positive program to calibrate each instrument of Item 26 to a known standard within 6 months of any test.	7	6.1.2
34.	Ability to calibrate pyranometer to determine the direct component of the insolation when in a tilted position.	7	6.1.2.1
35.	Evidence that the laboratory will use ASHRAE Standard 41.1-74 in measuring temperatures during tests.	7	6.2.1
36.	Assurance that the accuracy and precision of temperature measuring devices meets the requirements of Para 6.2.2 of AHSRAE Standard 93-P.	7	6.2.2
37.	Adequacy of provisions for differential temperature measurement.	8	6.2.3
38.	Assurance that the smallest scale division of all temperature measuring devices does not exceed twice the required precision of the device.	8	6.2.4
39.	Identification of flow devices and assurance that measurements made therewith have accuracy within + or - 1% of the measured value in mass units.	8	6.3.1
40.	Proof that strip chart recorders have an accuracy of + or - 0.5% of full scale and a time constant under 1 second.	8	6.4.1
41.	Assurance that any electronic integrators used can provide results equal to or better than 1% of measurement.	8	6.42
42.	a. Proof that the laboratory uses measuring techniques for nozzle throat pressures accurate to + or - 2% of absolute pressure. b. Assurance that instrument scale divisions are less than twice the specified accuracy.	8	6.61
43.	a. Assurance that manometer calibration is accurate within + or - 1% of any reading. b. Proof that manometer scales do not exceed 2% of reading.	9	6.62
44.	Showing that manometer for measuring collector Δp has an accuracy of at least 25 Pa (0.1" of water).	9	6.6.3
45.	Assurance of provisions to calibrate time and mass measurements to an accuracy of + or - 0.20%.	9	6.7
46.	Ability to measure wind velocity to + or - 0.8m/s (±1.8mph)	9	6.8
47.	a. Degree to which the laboratory's test configurations are identical to Figs. 1, 2, 3, 4 of ASHRAE Standard 93-P.	11	7.1

	CRITERIA FOR FORM SARIF-2.	Page	Para.
	b. Number of test stands of Fig. 1 configuration.		
	c. Number of test stands of Fig. 2 configuration.		
	d. Number of test stands of Fig. 3 configuration.		
	e. Number of test stands of Fig. 4 configuration.		
48.	Degree to which ambient temperature measuring device conforms to standard NOAA device as described in paragraph 7.12 of ASHRAE Standard 93-P.	11	7.1.2
49.	Degree to which need to measure direct component of insolation is recognized as by use of pyrheliometer.	11-12	7.1.3
50.	Availability of calibrated flow element for low air flows when nozzle diameters would be less than 0.025m (1").	15	7.2.8
51.	Demonstrated capability of the air reconditioning apparatus to control air temperature to collector within + or - 1.0°C (1.8°F).	16	7.2.10
	Indoor Testing by Simulator.		
52.	Degree of assurance that spectral qualities of radiation produced by the simulator meets the energy spectrum in this paragraph of ASHRAE Std. 93-P.	16	7.3.1
53.	Degree of assurance that absorptivity of the selected surface specified does not change over 1% for a change in radiation flux from 0.45 to 0.75 of one solar constant.	17	7.31
54.	Degree to assurance that the solar simulator flux does not vary over 7% over the test plane used.	17	7.3.2
55.	Assurance that 95% or more of the energy output of the simulator appears within a 10° subtended angle.	17	7.3.3
	Testing.		
56.	Degree to which laboratory shows its ability to determine the collector time constant.	19-20 22	8.2.2 8.3.1
57.	Assurance that laboratory is equipped to test at one or more incident angles other than normal as required to determine the factor "b" used in Equation 8.14.	20-21	8.2.3
58.	Assurance that the laboratory can perform all facets of the required testing,- 1, by outdoor test, and/or 2, by indoor simulation.	22-25	8.3.2
59.	Assurance that the laboratory can perform the tests to determine the collector incident angle modifier for all collectors it is capable of testing, as per paragraph 8.3.2.	25	8.3.3

CRITERIA FOR FORM SARIF-2.	Page	Para.
60. Assurance that laboratory has the expertise to accurately calculate the collector time constant, either by hand or by computer.	26	8.4
61. Assurance that laboratory has the expertise to accurately calculate the required data points and to provide a least squares fit to the applicable second order polynominal.	27	8.5
62. Assurance that laboratory has the expertise to accurately compute the collector incident angle modifier.	28	8.6
63. Assessment of reliability with which the laboratory is capable of providing all applicable information from tests of specific collectors required by Table A 13.	30 50-51	A-13
64. Degree to which laboratory is able to furnish all information required in Table 14 for each collector tested.	52-52A	A-14
General.		
65. For University laboratories, - degree of supervision of students performing test duties.		
66. Assessment of intangibles observed during the analysis of the laboratory's proposal and correspondence.		

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16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

In fulfilling its responsibilities under the National Program for Solar Heating and Cooling of Buildings established as a result of the Solar Heating and Cooling Demonstration Act of 1974 (PL 93-409) and related legislation, the Energy Research and Development Administration (ERDA) requested the National Bureau of Standards (NBS) to develop criteria for assessing the capabilities of laboratories for testing solar collectors, to identify those laboratories qualified to test solar collectors, and to develop a plan for the certification of solar collectors.

NBS engaged the professional services of ARI Foundation, Inc. (ARIF), a subsidiary of the Air-Conditioning and Refrigeration Institute (ARI), to identify laboratories qualified to test solar collectors and to develop documentation for a solar collector certification program. ARI is a national trade association of manufacturers of air-conditioning and refrigeration equipment with established experience and background in standards development for HVAC equipment and the conduct of certification programs for such equipment.

This summary report covers the identification of qualified solar collector testing laboratories. It discusses the procedures used by ARIF, the results of their evaluation and lists the laboratories evaluated as qualified to test solar collectors in accordance with American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) Standard 93-77.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

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